Gravel sediment tracing from small torrents to trunk channels using pit-tags method: A case study from the upper Guil catchment (Queyras, French Alps)

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Mountain streams : processes, channel morphology and knickpoint dynamics (co-organized)

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1 Background and scientific context

In mountainous areas, especially in large catchments with torrential tributaries, the production and sediment transport significantly increase flood impacts in the valley bottoms. The quantification and characterisation of sedimentary transfers are therefore major challenges to provide better flood risk management. As a part of SAMCO (ANR 12 SENV-0004 SAMCO) project, for mountain hazard assessment in a context of global changes, we tried to improve the knowledge of these hydromorphological systems at both spatial and temporal scales, by identifying sediment supply and sediment dynamics from torrential tributaries to the trunk channel. A sediment budget was used as a tool for quantifying erosion, transport and deposition processes.

This research is focused on a part of the sedimentary budget to understand the torrential processes and to define debris-flow's contribution. It is localized on the Upper Guil catchment, prone to catastrophic flash floods in active channel and alluvial fans. It is characterised by huge sediment transport coming from small torrential tributaries. In this study, we intend to highlight sediment dynamic between small torrential channels and its connection with gravel-bed streams, and characterize the sediment volume mobilized during a large debris-flow event.

2 Study area

The upper Guil catchment (Queyras - 317 km²) is characterised by a lithology composed of 90-95% of shale (Fig.2-a), supplying the river bed in huge fine and coarse sediment. Functioning in high magnitude/low frequency (Fort et al., 2002), the Guil River is subjected to flash-flood events. The volumes of sediment mobilized during the 100-year flood event in1957 have been estimated at 330.000 m³ (Koulinski, 2002). Sediment load in the main channel of the Guil River results from erosion in small torrential tributaries, as the Peynin catchment (Fig.2-b). Operating in debris flows, the volumes deposited during June 2000 (RI-30 year flood event) have been estimated at 12.000 m³ aggraded on the Peyronnelle fan (Fig.2-c) (Einhorn, 2003).

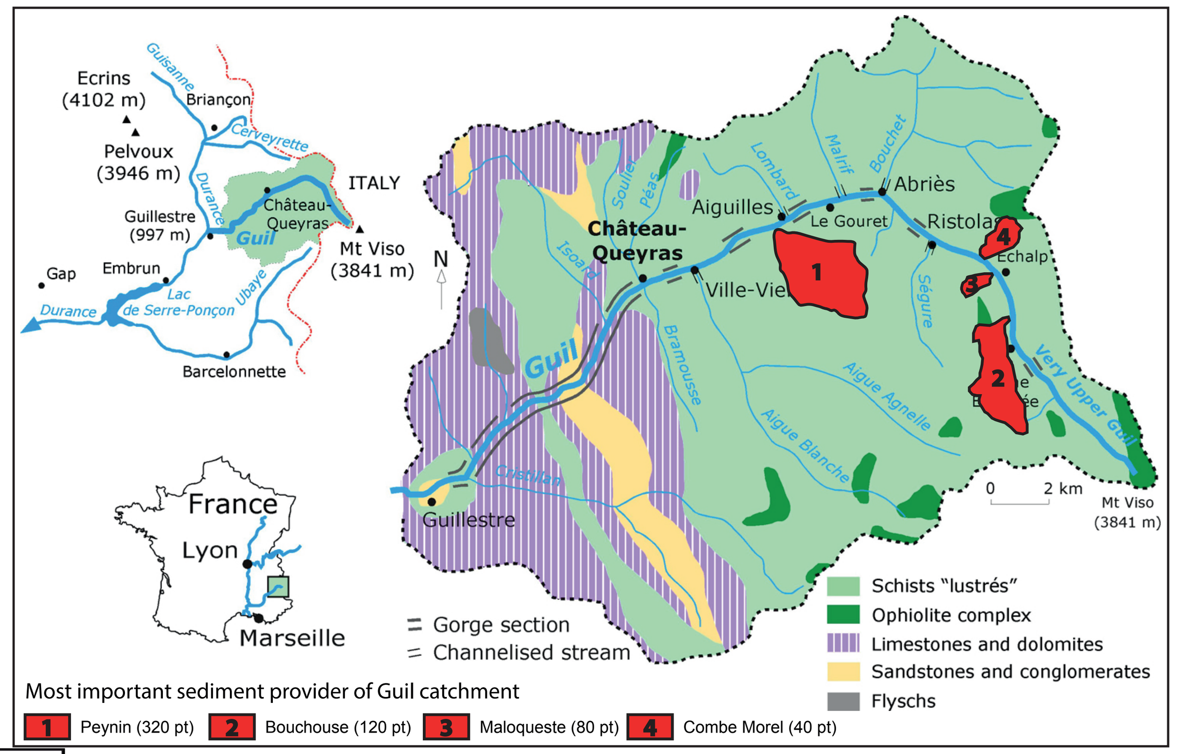


Fig.2-a : Inset map of France with location of Guil River and geological structure (Lissak et al., 2015)

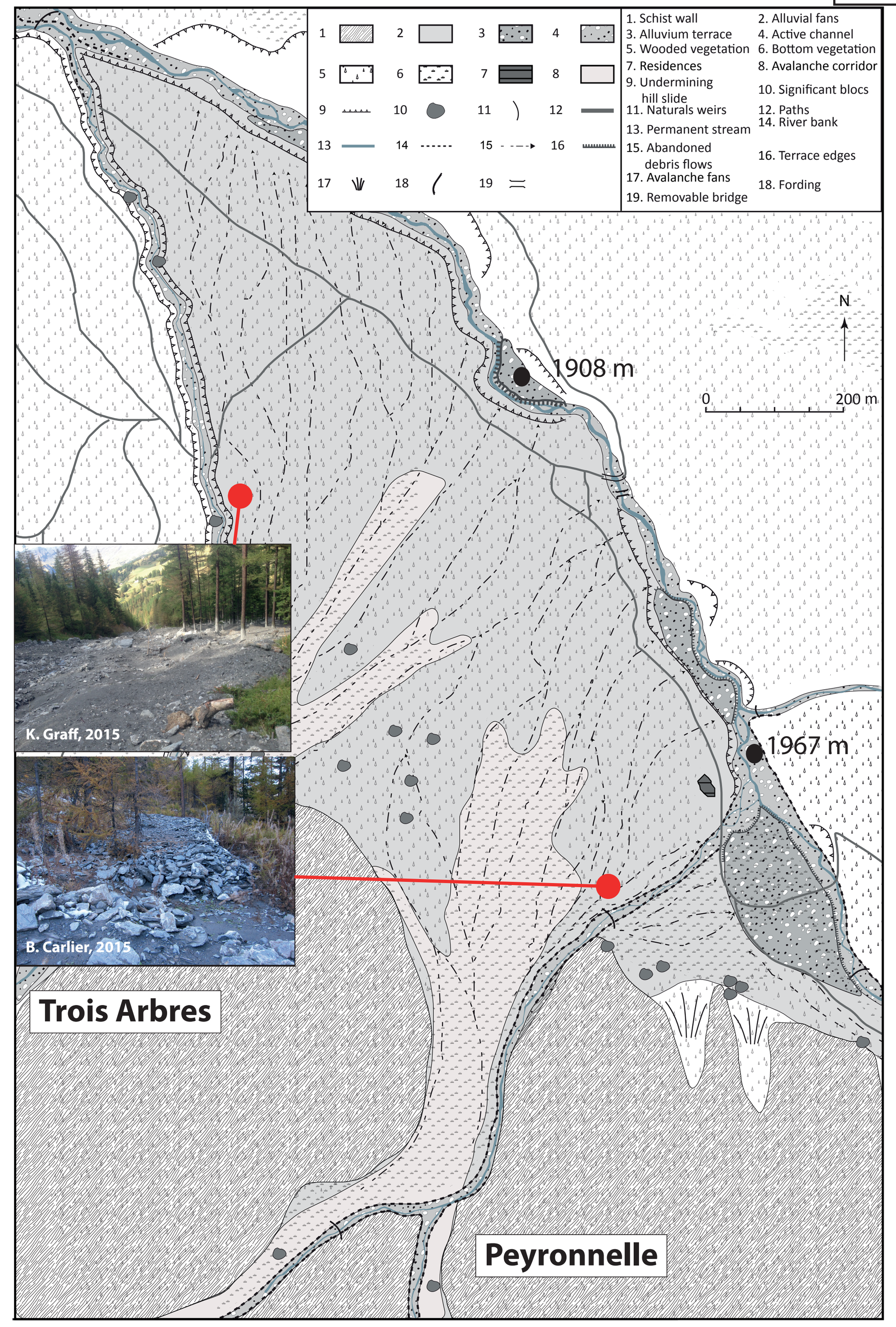


Figure 2-c : Geomorphological map of the Peyronnelle and Trois Arbres fans and extent of the debris flows of august 2015

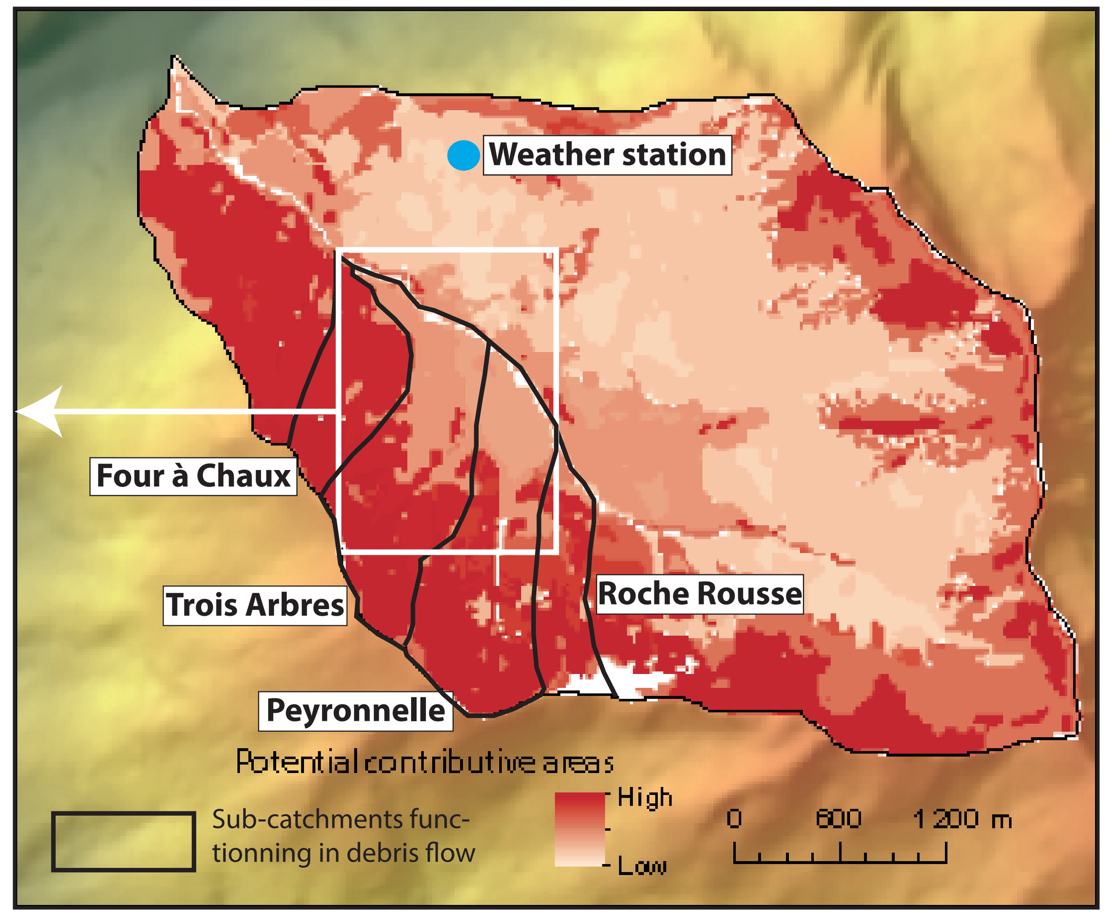


Figure 2-b : Slope contribution to sediment supply in the Peynin catchment (Lissak et al., 2015)

Left bank		Right bank
- Strike side : high torrential and debris flow activity - Steep slope : mean 50%	Peynin	- Dip side : operating in solifluction and creeping processes -Slope : mean 30 %

Spatial and temporal sediment dynamics are studied on four most important subcatchment, in the upper Guil catchment (Fig.2-a). This poster is especially focused on the Peyronnelle catchment (Fig.2-b) where an important debris-flow event has been observed during August 2015.

3 Materials and methods

a) Pit tags setting in the Peyronnelle catchment

Grain-size representativity of the Peyronnelle has been tested in order to estimate the size of the bedload transported (Graff, 2015). Pit-tags (p.t.) method has been used to estimate spatial dynamics in the Peyronnelle catchment during a debris flow event (fig.3-a). In the Peyronnelle stream, 320 p.t. were installed in 10 injection sites along the thalweg (Fig.3-b). Each monitored particle was measured (3 axes- Long/Intermediate/Short) (Fig.3-a).

Pit tags have been spreading around 30% in the thalweg, and 70% in left and right banks. Five injection forms were determined and recorded to trace source of receivers displacement.

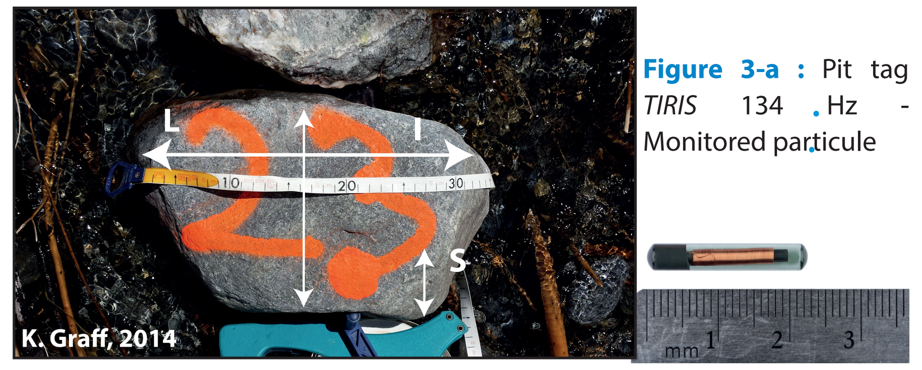
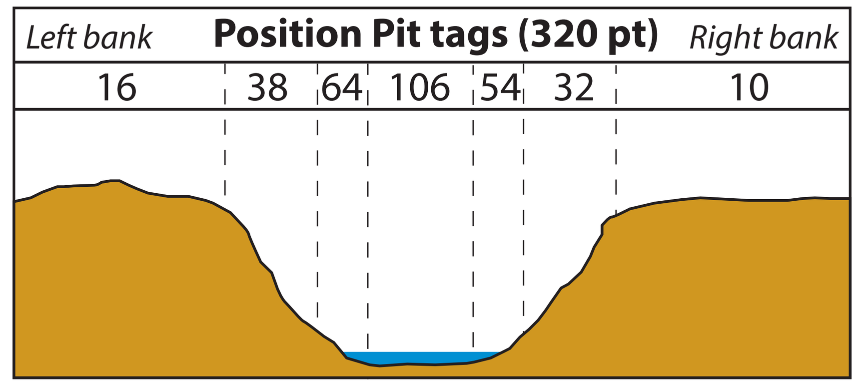


Figure 3-a : Pit tag TIRIS 134 . Hz - Monitored particule

- A Differential Global Positioning System (DGPS) has been used to locate and map each monitored particules. Precision is estimated from 0,5 m for horizontal dimension to 1,5 m for vertical dimension.
- A meteorological station was implemented in 2014 on the right side of the Peynin (Fig.2-b). Rainfall were estimated every hour then been computed for everyday.



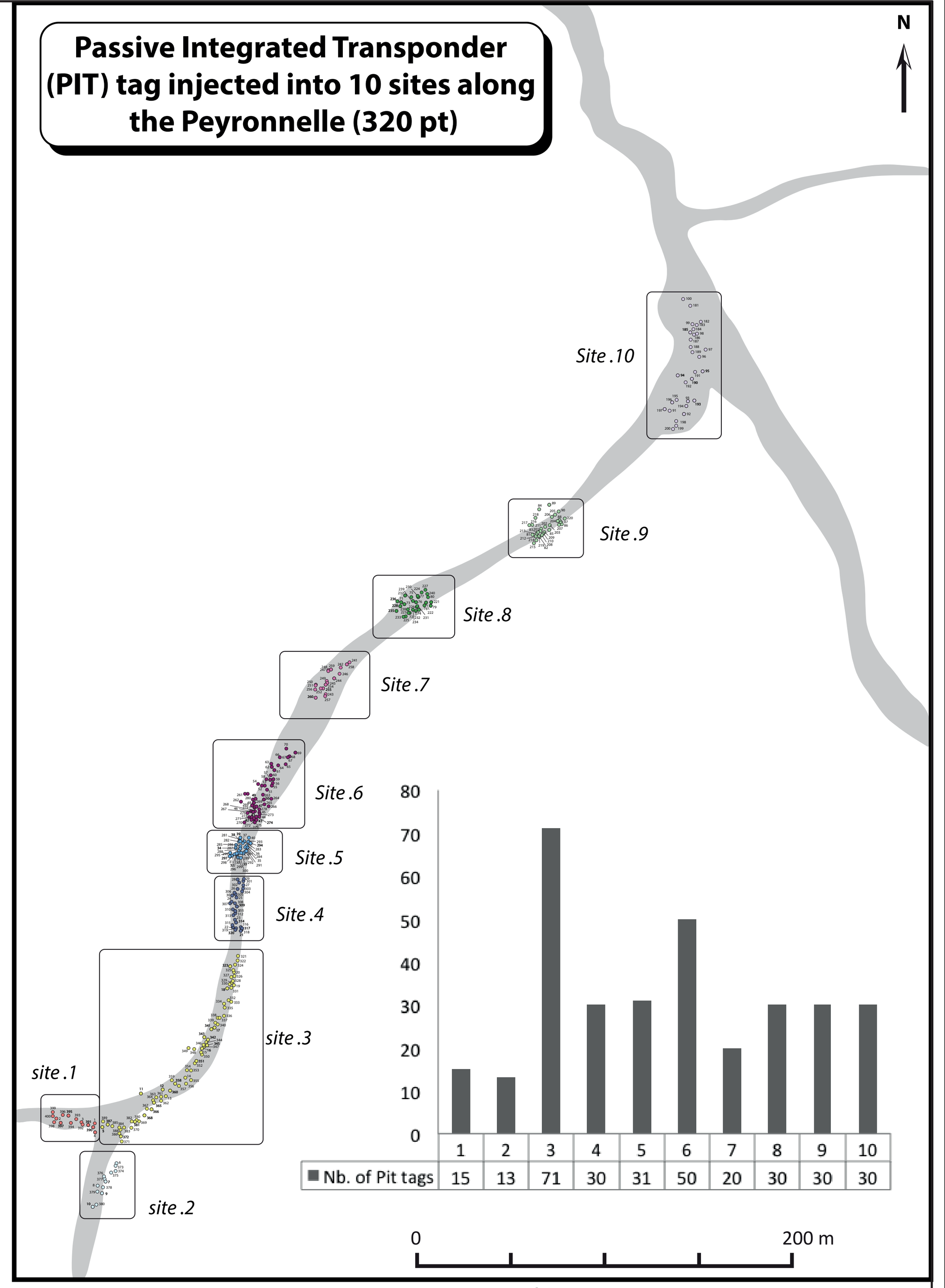


Fig.3-b : Injections site of Pit tags

b) Estimation of debris flow volumes

Three equations have been used to estimate volumes mobilized during the debris flow of August 2015. The first equation used **(1)** is estimated from field mapping and observations on alluvial fan. Equations **(2)** and **(3)** are theoretical estimations of the mean and maximum volume mobilisable by the torrential catchment. From these equations we will estimate the volume mobilized in the Peynin during a debris flow.

(1) $$V_f = S\,H$$

Where V_f is the volume dropped on the Peyronnelle fan (in m³), S is the area of debris flow (in m²), H is the height of debris flow (in m).

(2) $$V_m = 39\,A_d^{0.61}\,S_f^{1.5}\,IG$$

Where V_m is the average of debris flow mobilisable (in m³), A_d is surface of catchment (in m²), S_f the slope of the fan (in %), IG is a geological index (in Remaître, 2006).

(3) $$V_{max} = \begin{cases} L_c\,(110 - 2.5\,S_f) & \text{if } 15 < S_f < 40\,\% \\ L_c\,(6.4\,S_f - 23) & \text{if } 7 < S_f < 15\,\% \end{cases}$$

Where V_{max} is the maximum debris flow mobilisable (in m³), L_c is the lenght of the torrent (in m) (in Remaître, 2006).

4 Results

a) Meteorological context of the debris flow (August, 2015)

Overnight on August 8 and 9, 2015, an important rainfall event (23 mm) has been recorded at the weather station in the Peynin catchment, due to intense storm cells (Fig.4-a). Debris particules have been found in all sub-catchment, located on the left bank of the Peynin River (Four à Chaux, Trois Arbres, Peyronnelle, Roche Rousse - Fig.2-b).

Rainfall recorded in the upper Guil was not sufficient to switch to flash-flood regime in the Guil and tributaries.

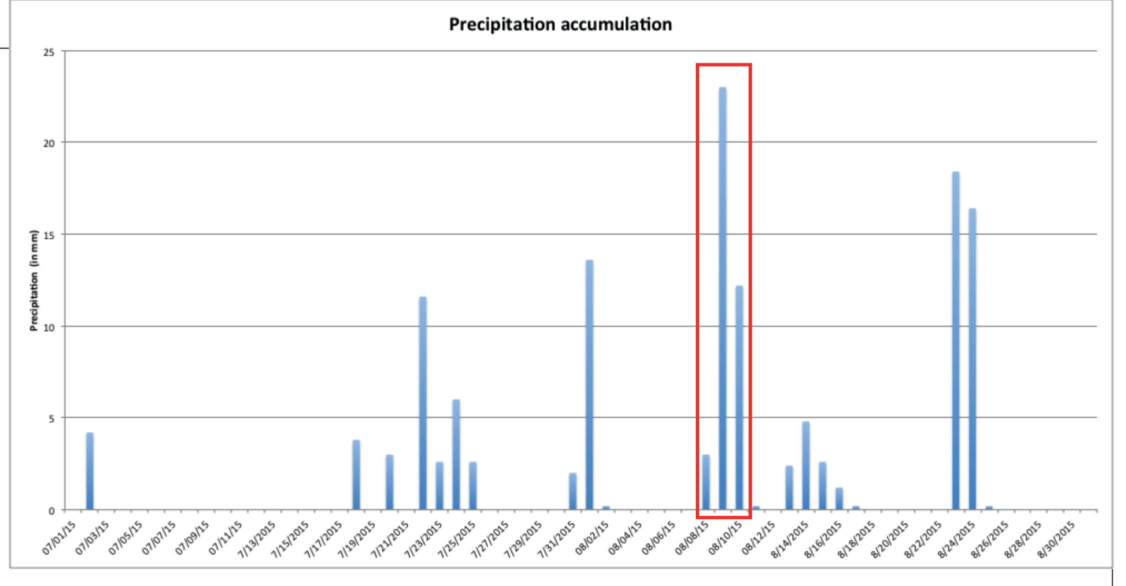


Figure 4-a : Meteorological data of the Peynin in July - August

b) Trajectories and grain-size pattern

During the debris flow event (Fig.4-b), 101 monitored particules have been funded (e.g. 31%). They were gathered in 5 different groups : 35% of the total p.t. found in the Peynin, 16% in the downstream of the Peyronnelle, 12% in old debris flow channel, 25% in the main channel of the Peyronnelle and 12% in apex of alluvial fan (Fig.4-d).

Average distances covered by monitored sediments are in between 58 m and 384 m (Fig.4-d). The maximum distance observed is 720 m. Only 9% of the total p.t. found have not moved.

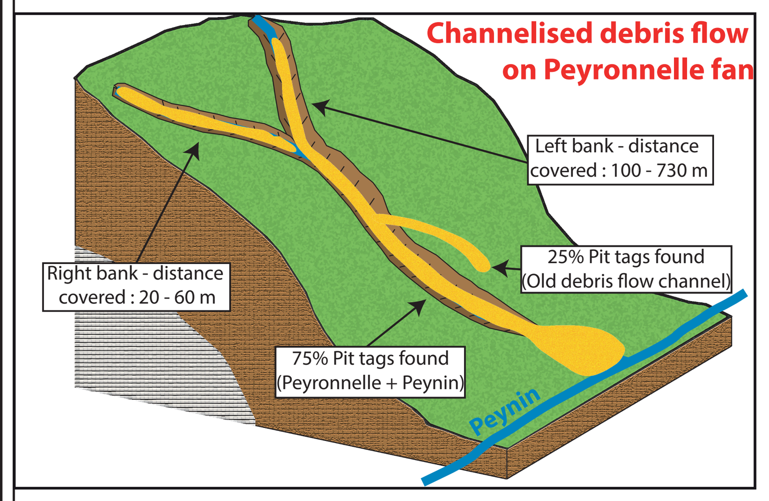


Figure 4-b : Schematic representation of the debris flow of August 2015 on the Peyronnelle fan

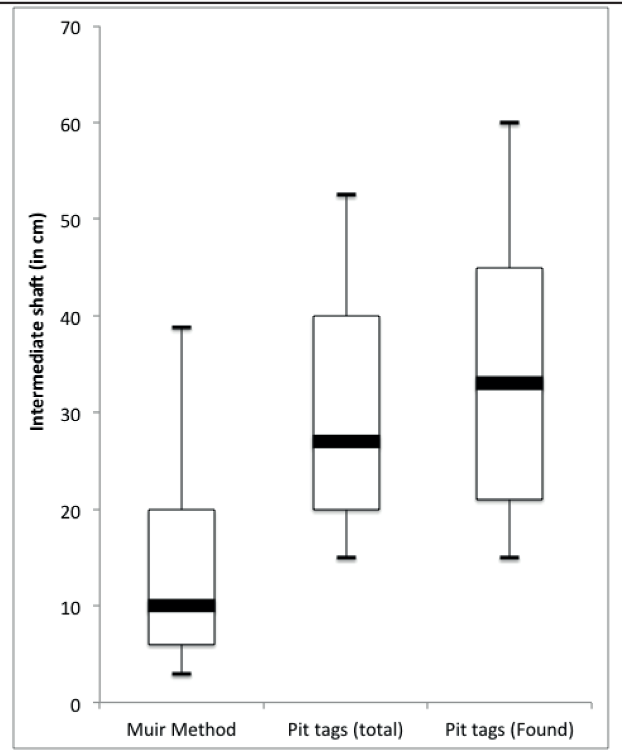


Figure 4-c : Grain size box plot

The grain size of the found Pit Tags, and the average geometry, were three times higher than size set by Muir method (Fig.4-c).

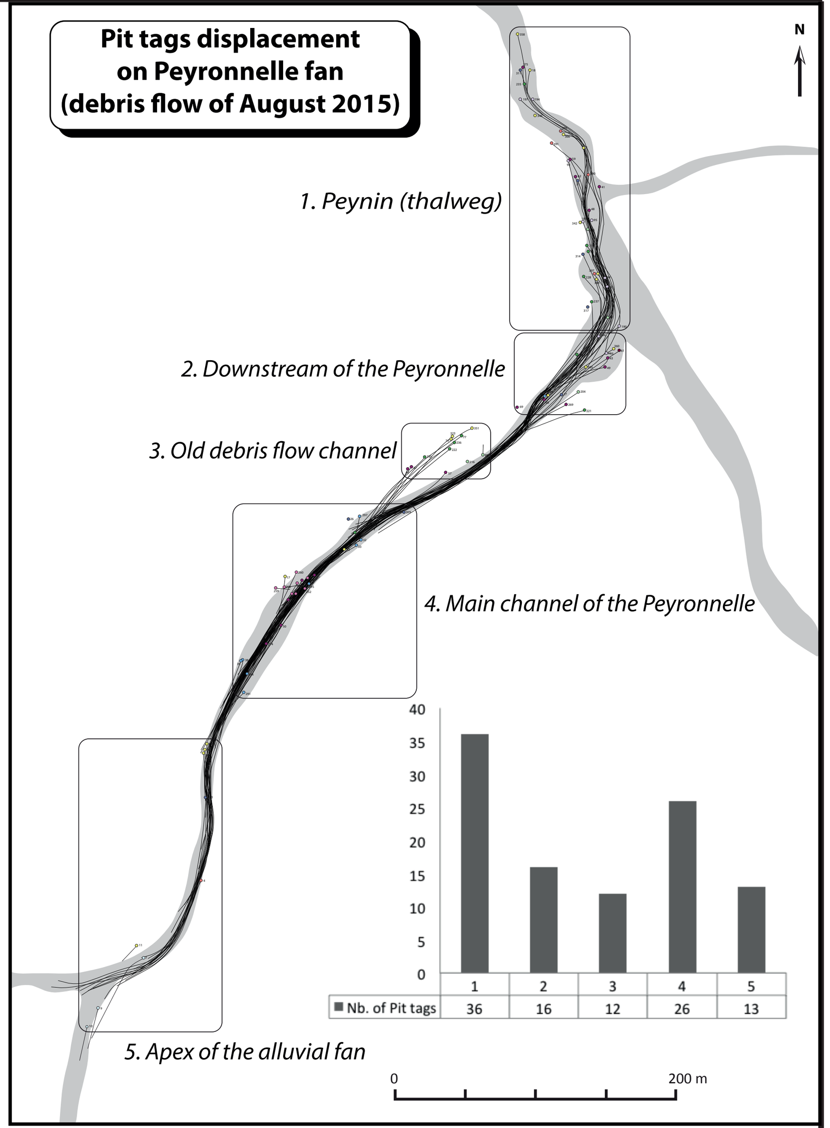


Figure 4-d : Path covered by Pit tags (101 pt found)

c) Mobilized volumes of debris flow

Volume metered on alluvial fan

Area = 16.000 m²

Minimum height = 1,2 m → $V_{f(min)}$ = **19.500 m³**

Maximum height = 1,8 m → $V_{f(max)}$ = **29.000 m³**

$V_{f(mean)}$ = **24.250 m³**

Estimation of theoritical volumes

A_d = 1,007 km² ; S_f = 25 % ; L_c = 619,12 m ; IG = 4

V_m = **31.000 m³** V_{max} = **29.500 m³**

$V_{(mean)}$ = **30.250 m³**

Estimation of volumes deposited in the Peynin

$V_{(\%)Peyronnelle} = V_{f(mean)} / V_{(mean)}$

$V_{(\%)Peyronnelle}$ = **80 %**

$V_{(\%)Peynin}$ = 100 % - 80 % = **20 %**

$V_{Peynin} = 30.250\ V_{(\%)Peynin}$

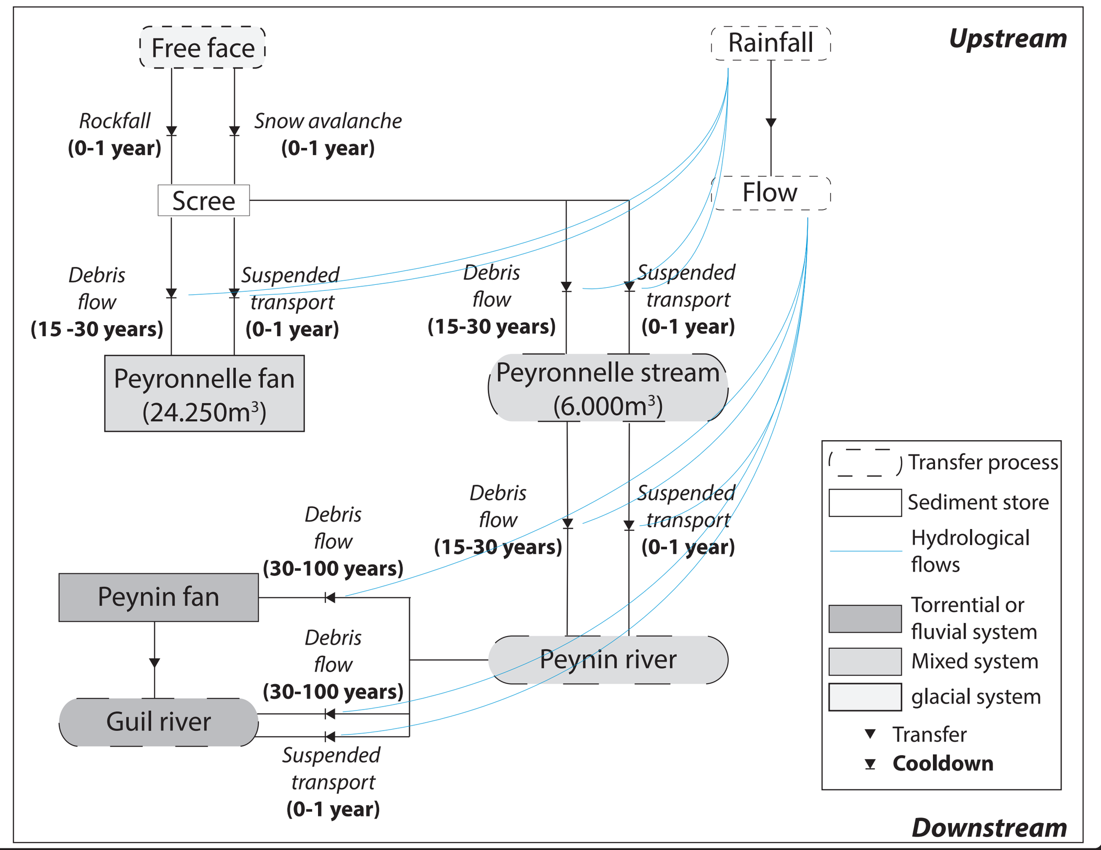
V_{Peynin} = **6.000 m³**

Volumes mobilized in the Peyronnelle is estimated at 24.250 m³ (margin of error: 17%). Volumes mobilized on the Peynin have been estimated at 6.000 m³ (margin of error: 25%). Sediment volumes mobilized during a debris is significiant (+30.000 m³) but its contribution in the Peynin thalweg is only 20% of total sedimentary volume.

5 Conclusion

Debris flow occuring in August 2015 has mobilized monitored sediment on the Peyronnelle catchment. Distance covered by Pit tags have reached 720 m and average distance for each group is in between 58 and 384 m. After this event, 75% of monitored sediment have been found in Peyronnelle and Peynin thalweg and 25% have been found in old debris flow channel. Left bank tributary of the Peyronnelle has a much greater activity [100 ; 730 m] than right bank tributary [20 ; 60 m]. Controlling factor are directly related to steepness of the slope, allowing the displacement of the particles by gravity flow. Height of the bank and channel width regulate acceleration of debris flow. Total volumes mobilized during debris flow were estimated to be more than 30.000 m³. Results therefore highlight the pulsating character of sediment fluxes associated with high magnitude and low frequency events and indicate the strongest functionality of debris-flow dominated channels in the Peynin catchment.

These data have to be used to discuss lag time, processes and thresholds. These three elements are needed to observe significant sediments fluxes. Sediment supply has also to be precised as it is a critical importance in the triggering of debris-flow events.



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